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ON THE BIONOMICS OF MOSQUITOES IN IRRIGATED AREAS OF ALBERTA

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THE UNIVERSITY OF ALBERTA

ON THE BIONOMICS OF MOSQUITOES IN IRRIGATED AREAS OF ALBERTA

A DISSERTATION

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES

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ABSTRACT

Four genera and sixteen species represent the sub-family Culicinae in the irrigated areas of Alberta, namely Anopheles with one species, Culex with one species, Culiseta with two species, and Aedes with twelve species. The sub-family Chaoborinae, the status of which at present is uncertain, is represented by one genus Chaoborus and two species. It is demonstrated that more than 95 per cent of the mosquito population in a normal year develops in irrigation water. The relative abundance of the larvae and adults of the seven most important species in three irrigation districts is recorded for weekly periods during the season. Mosquito species of these irrigated areas are crepuscular and nocturnal in habit. Precipitin tests to determine the sources of the blood were made. Approximately one per cent of the females tested had two different hosts. Larvae of Culiseta inornata were found to be parasitized by a fungus, tentatively identified as Coelomomyces sp. A list of possible predators of mosquito larvae is included.

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ON THE BIONOMICS OF MOSQUITOES IN IRRIGATED AREAS OF ALBERTA

I INTRODUCTION

Mosquitoes in irrigated areas have been a cause for concern in the United States and to a lesser degree in other countries for many years. In Canada this mosquito problem received its first attention from Brown (1954). In 1955 a rapid survey was conducted of all irrigated areas of Alberta and Saskatchewan. This survey showed that mosquitoes were a serious problem in irrigated areas. The benefits of irrigation were reduced by the multitude of mosquitoes emerging from the great numbers of suitable breeding places provided by it. Apart from the annoyance and discomfort that mosquitoes impose on man and livestock, economic losses through (1) reduction in beef and milk production, (2) reduction in efficiency of the agricultural and other workers, (3) interference in recreation, (4) reduction in real estate value, and (5) spread of diseases, are possible. A concentrated study of the mosquito problem in irrigated areas of Alberta was started in 1956 and continued in 1957.

II OBJECTIVES

The objectives of this study were to determine the seasonal changes in development, abundance and dispersal of economically important mosquitoes in irrigated areas of Alberta. It was also hoped to gain new information on the influence of new irrigation development on the development, abundance and habits of mosquito species native to dry-land prairie.

III IRRIGATION IN ALBERTA

A. Historical

Irrigation practices are confined in countries where precipitation is less than ten inches. Irrigation has been practiced for at least 4000 years in Egypt on the Nile and in India and China for several centuries. In South America 800 years ago irrigation flourished. In the 1860's and 1870's in Utah irrigation was very successfully practiced and from these early practices, the laws and practices of irrigation as we know them in Alberta were formed.

Irrigation in Alberta started in 1879 when John Glen diverted water from Fish Creek near Calgary, Alberta, to irrigate the first farm. In 1887 the Mormons began irrigating at Cardston and by 1894 the Northwest Irrigation Act was passed on the advice of Colonel J. S. Dennis, at that time Land Surveyor for the Federal Government. From the time of the passing of the Act, irrigation has advanced rapidly to the present date, and there are now approximately half a million acres receiving water in Alberta.

In 1915 the Alberta Irrigation District Act was passed by the Alberta Government. It stated that districts should be organized, bonds floated and money applied against the land and the irrigation operations carried out under cooperative arrangements. Development by private capital is no longer practiced in Alberta and most projects are constructed and supported by the Government.

B. Location and Limits

All existing irrigation projects in Alberta are located south of the Red Deer river

between the 4th and 5th meridians. Figure 1 shows the existing and proposed irrigation developments in Alberta.

C. Climate and Weather

The climate of southern Alberta, where most irrigation is practical, is typical of the climate of the high plains region of western Canada. It is characterized by an average annual precipitation of 11 - 15 inches, with frequent drought, and in some areas frequent hot dry winds resulting in high evaporation. These chinooks, strong, warm, southwesterly winds reduce the soil moisture rapidly. Prolonged periods of chinooks can be detrimental to plant growth in the summer. Long, warm, sunny summer days and the long frost-free period make this area suitable for irrigation development.

The weather during 1956 and 1957 was typical for the area. The temperature for each year was slightly higher than the mean for the period 1902 - 1954. Figure 2 shows the mean monthly temperatures, precipitation, and wind speed at Lethbridge, Alberta, for the period 1902 to 1954, and the years 1956 and 1957.

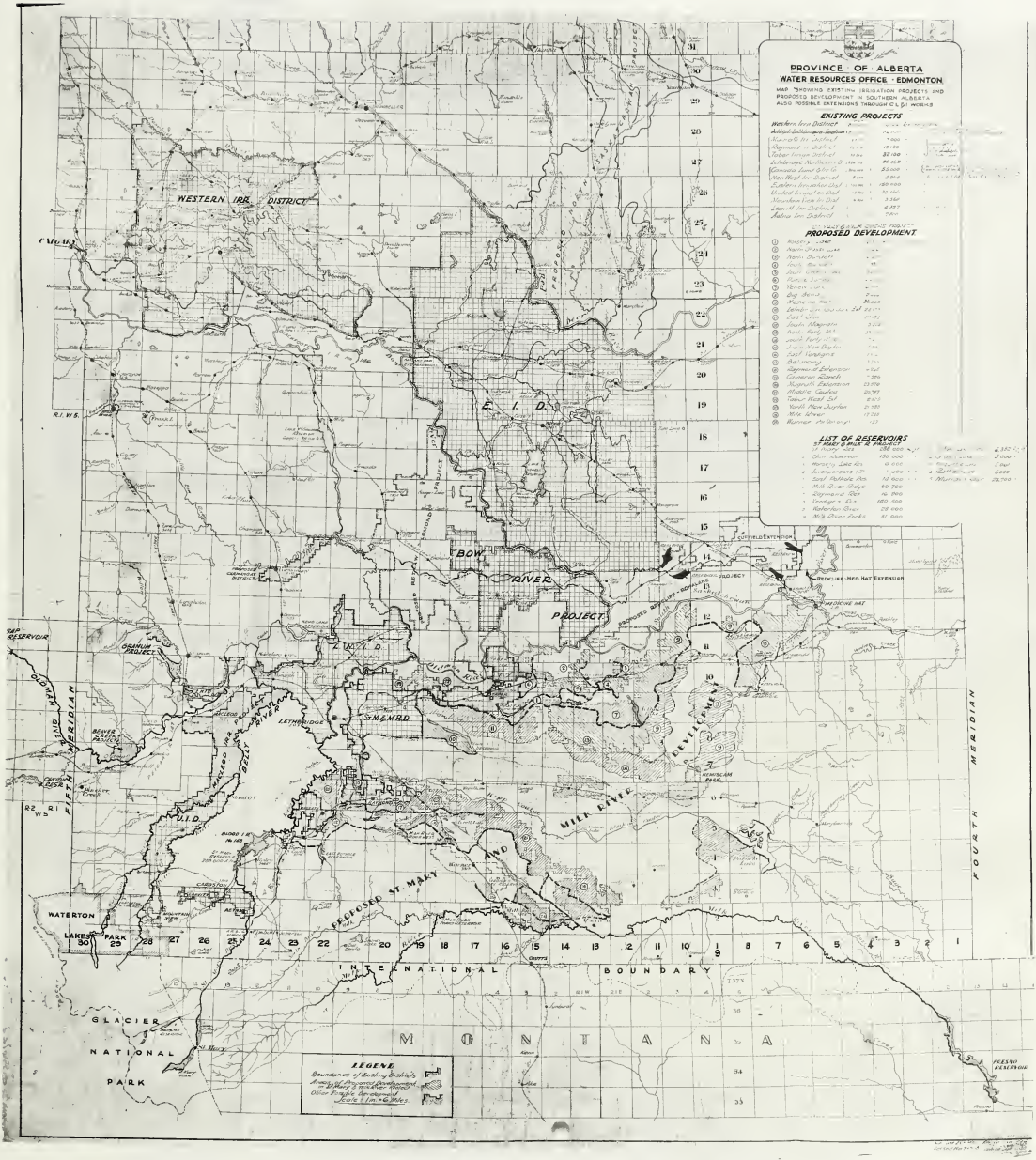

Figure 1. The existing and proposed irrigation developments in Alberta.

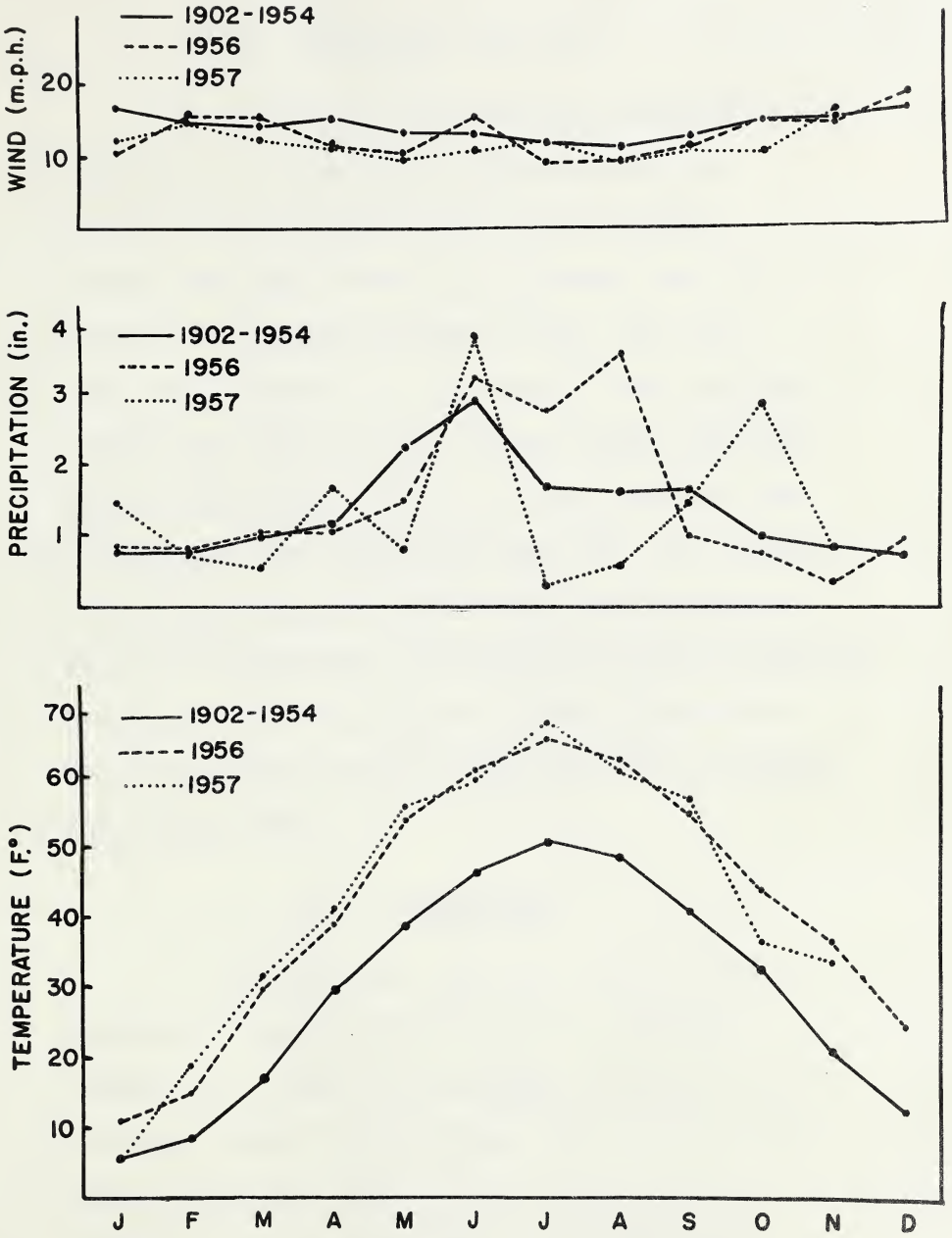

Figure 2. Mean monthly records of temperatures, precipitation, and wind at Lethbridge, Alberta, for the period 1902 - 1954, and for the years 1956 and 1957.

D. Topography and Soil

In general the existing irrigation districts of Alberta are of undulating to gently rolling topography, cut by deeply eroded coulees. There is a gradual drop in elevation of approximately 10 ft. per mile from the southwest to northeast. The existing irrigation districts lie in the brown and dark brown soil zones. Soils in this area are low in nitrogen and organic matter, but lend themselves favorably to artificial fertilization. Prior to irrigation development, moisture was the principal limiting factor in crop production. The topography and soil make this area suitable for irrigation.

IV PROCEDURES

In 1956 the two study plots in the Eastern Irrigation District were selected (Figure 3). Each of them was 16 square miles in size. Plot 1 was located in an extensively farmed irrigable area. Plot 2 was located outside the irrigable area in grazing land and served as a check for Plot 1. Any seepage and overflow from canals cutting through Plot 2

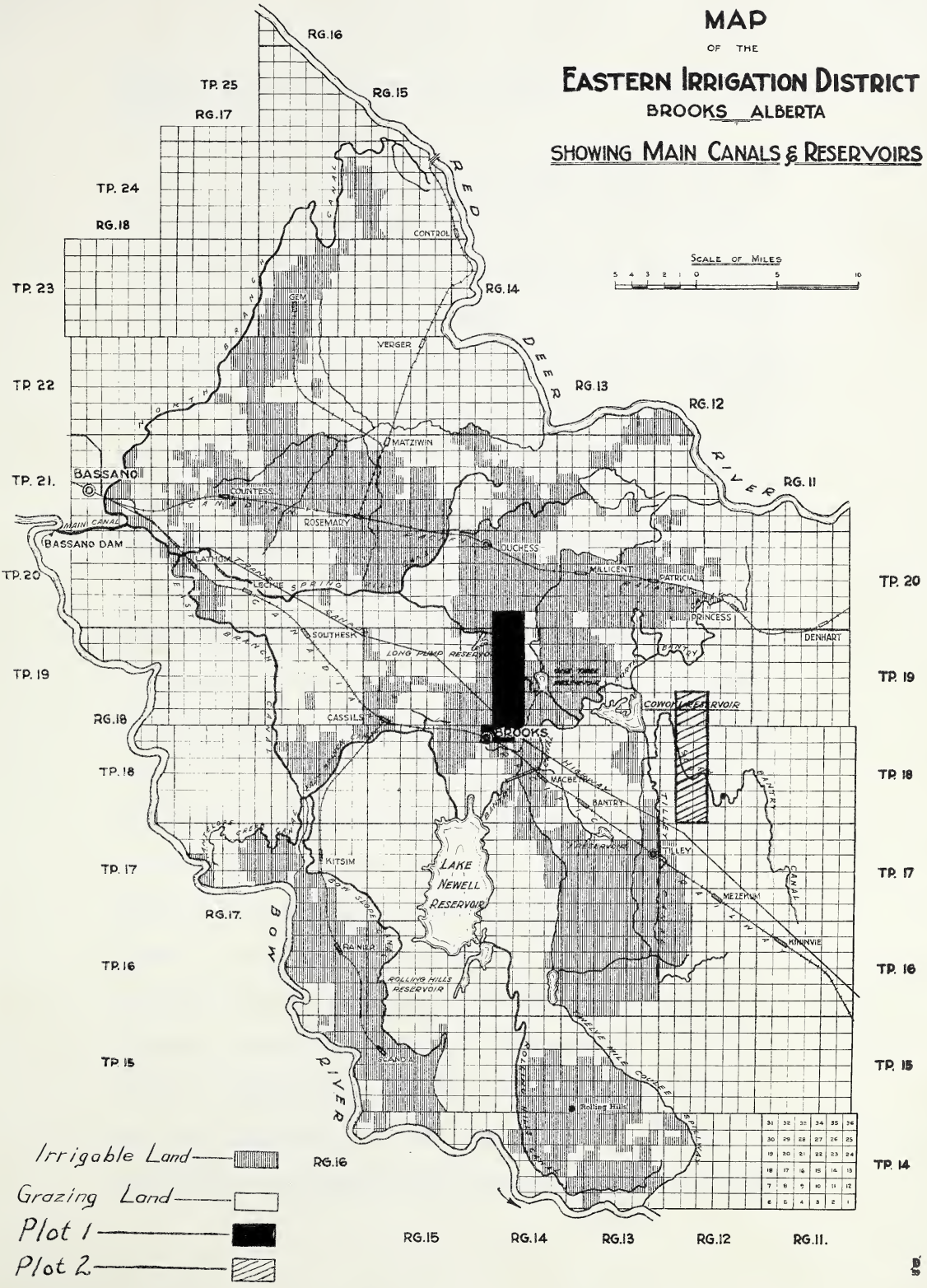

Figure 3. The location of the plots studied in 1956 in the Eastern Irrigation District.

was disregarded from the standpoint of mosquito larval production.

The plots were surveyed weekly and all the breeding places were marked. The mosquito production was estimated by taking 20 dips with a quart size dipper at random around the periphery of every pool existing in the plot that week. All fourth instar larvae and all pupae were counted in each dip. A representative sample of fourth instar larvae was taken from each dip for identification purposes. The size of each pool was recorded in square yards. The mosquito production of each pool was expressed as a production index defined as the product of the average number of larvae per dip and the surface area of the pool in square yards. This method of estimating the population and the use of this production index was reported by a group of United States Public Health Service workers in their First Progress Report on Mosquito Investigations in the Milk River Irrigation Project, Montana, Anonymous (1953). The method provides only a comparative estimate and does not give an absolute value of the population. It has the advantage of rapidity and requires no cumbersome

equipment.

The total salt concentration and the pH of the water from the mosquito larval habitats was determined. The salt concentration was measured with a conductivity bridge and the pH was measured with a Beckman pH meter.

Two visual attractant traps (Figures 4 and 5) were used to sample adult populations. This type of trap was developed by Haufe and Burgess (unpublished). The striped cylinder and disc assembly is rotated about a vertical axis clockwise, when seen from above, by a small electric motor. This movement attracts the mosquitoes to the cylinder and once close to it, they follow either the black or the white stripe to the top of the cylinder where they are sucked by a fan into a cone below the cylinder. An interchangeable cartridge fits into the cone from below. In the cartridge there are fifteen discs which can be set to drop at regular intervals by means of a timer and electromagnet. The discs dropped at hourly intervals.

One trap (Figure 4) was operated in a sheltered area in the town of Brooks, Alberta. The other (Figure 5) was operated 1.5 miles east

Figure 4. The location of Trap 1 used in sampling adult populations at Brooks, Alberta, May to September, 1956.

Figure 5. The location of Trap 2 used in sampling of adult populations near Brooks, Alberta, May to September, 1956.

of the first in an open pasture. No traps were operated in the check plot because electricity was not available. These traps were operated 24 hours a day, and all the mosquitoes caught were identified.

All blood-engorged females were separated and the blood meals identified by precipitin test. Blood meals of engorged females collected in barns and farm yards were also identified.

In 1957, three plots were studied, each six square miles in size and each in a different irrigation district. Plot 1 was in the Eastern Irrigation District near Rolling Hills; Plot 2 was in the P.F.R.A. Irrigation Project near Hays; and Plot 3 was in the Big Bend Project of the St. Mary's River Development near Taber.

Plot 1 was selected because it was in one of the oldest irrigation developments in Alberta, had poor drainage facilities, and its major industry was livestock production. Plots 2 and 3 were selected because both had been in operation for six years. The former has proper drainage facilities and its chief

industry was cereal crop production. The latter, by contrast, had poor drainage facilities and produced mainly row crops.

Each of these plots was surveyed weekly and the larval production index determined by the method used in 1956.

The adult population was sampled by one visual attractant trap in each plot. The traps were set up in farmers' yards under conditions as similar as possible.

Blood engorged females captured in the traps were kept and the blood meals identified.

V DATA OBTAINED

A. Species Present

During the 1956 and 1957 seasons, 18 species of the family Culicidae, belonging to the sub-families Culicinae and Chaoborinae, were found in the irrigated areas of Alberta. The list was compiled from larval and adult collections.

	Species occurred as		
	L*	♀	♂
Sub-family: Culicinae			
Tribe: Anophelini			
Genus: Anopheles Meigen			
Sub-genus: Anopheles Meigen			
Species: earlei Vargas	x	x	x
Tribe: Culicini			
Genus: Aedes Meigen			
Sub-genus: Aedimorphus Theobald			
Species: vexans (Meigen)	x	x	x
Sub-genus: Aedes Meigen			
Species: cinereus Meigen	x	x	
Sub-genus: Ochlerotatus Lynch-Arribálzaga			
Species: dorsalis (Meigen)	x	x	x
campestris (Dyar and Knab)	x	x	x
spencerii (Theobald)	x	x	x
flavescens (Müller)	x	x	x
nigromaculis (Ludlow)	x	x	x
riparius Dyar and Knab	x	x	x
sticticus (Meigen)	x	x	
intrudens Dyar	x	x	
cataphylla Dyar	x	x	

*L = larvae

	Species occurred as		
	L*	♀	♂
melanimon Dyar			x
Genus: Culiseta Felt			
Sub-genus: Culiseta Felt			
Species: inornata (Williston)	x	x	x
alaskaensis (Ludlow)		x	
Genus: Culex Linnaeus			
Sub-genus: Culex Linnaeus			
Species: tarsalis Coquillett	x	x	x
Sub-family: Chaoborinae			
Genus: Chaoborus Lichtenstein			
Sub-genus: Chaoborus Lichtenstein			
Species: americanus (Johannsen)	x	x	x
flavicans (Meigen)	x	x	x

Seven species of the sub-family Culicinae can be regarded as common pests in the irrigated areas of Alberta. These are in the order of importance, Aedes dorsalis, Aedes vexans, Culiseta inornata, Culex tarsalis, Aedes spencerii, Aedes campestris and Aedes flavescens. No other

*L = larvae

species appeared to be numerous enough to be classed as a serious pest.

It is possible that some females of A. melanimon (Burgess, 1957) were recorded as A. dorsalis because of the difficulty in distinguishing rubbed specimens.

B. Notes on Species

Anopheles (Anopheles) earlei

Larvae of this species were taken in very small numbers in all of the irrigation districts of Alberta. They were taken in roadside ditches (Figure 6), and field ponds, heavily overgrown with vegetation. The larvae were found in the heavily sheltered portions of the pools. The water in which they were found was rich in organic matter and usually carried a prolific growth of algae. Rempel, 1950, and Shemanchuk, 1952, have reported this species in sluggish overgrown streams. Larvae were not found in the irrigation ditches sampled probably because of the swift flow and the lack of overhanging vegetation. Few adults of this species were taken in the visual attractant trap in late July and early August.

Figure 6. The types of pools in which Anopheles earlei larvae were found.

Aedes (Aedes) cinereus

This species has been taken in very small numbers as larvae and adults. The larvae were found only in pools surrounded by willow. It is not a serious pest in the irrigated areas.

Aedes (Aedimorphus) vexans

This species is one of the most abundant in the irrigated areas of Alberta. Larvae were found in temporary pools in association with Aedes dorsalis, Aedes flavescens, Culex tarsalis, and Culiseta inornata. They were found in water with pH range between 7.73 and 8.48 and the total salt concentration between 499 and 1900 p.p.m. There were several broods during the season. Adults are troublesome to man and livestock. Shelter belts and tall vegetation appear to be the preferable adult resting place.

Aedes (Ochlerotatus) dorsalis

This species is one of the most abundant in irrigated areas of Alberta. It is found in temporary pools. Larvae can tolerate pH between 7.34 and 9.03 and total salt concentrations up to 22,450 p.p.m. At levels of total salts above

1900 p.p.m., larvae were found in association with A. campestris and at levels below 1900 p.p.m. in association with A. vexans, A. flavescens, A. spencerii, and C. tarsalis. Adults are abundant and can be encountered in great numbers even in the short grass pastures at almost any time of the day.

Aedes (Ochlerotatus) campestris

This species is common in the irrigated areas of Alberta. Larvae are found in pools with high total salt concentration, usually between 13,000 p.p.m. and 22,450 p.p.m. They were found in association mostly with A. dorsalis. Adults draw attention to themselves by biting whenever their habitat is disturbed even during the heat of the day.

Aedes (Ochlerotatus) spencerii

A common species in the irrigated areas of Alberta, but not as abundant as A. vexans, A. dorsalis, Culex tarsalis and Culiseta inornata. This species tolerates the same range of total salt concentration as A. vexans and A. flavescens. Adults will attack at any time during the day when their habitat is disturbed.

Aedes (Ochlerotatus) flavescens

This species is common in all the study areas. Larvae were present throughout the season in varying numbers. They seem to tolerate levels of total salt concentration below 1900 p.p.m. They appear only in pools which had dried out completely for at least two weeks before reflooding. Adults do not attack man very readily, but seem to prefer livestock.

Aedes (Ochlerotatus) nigromaculis

This species is present in very small numbers. According to Rempel (1953) it is common in Saskatchewan. Larvae were taken in shallow depressions in pastures in very small numbers. Adults were taken in the visual attractant traps.

Culiseta (Culiseta) inornata

This is one of the most abundant species in the irrigated areas of Alberta. During July, August, and September, larvae can be found in almost every pool. This species overwinters in the adult stage.

Adults do not attack man readily, but are most troublesome to cattle, especially after dark. They have been taken in the visual attractant traps as late as November 2.

Culex (Culex) tarsalis

This is one of the most abundant species in the study area. Like those of Culiseta inornata, Culex tarsalis larvae can be found in almost every pool during July, August, and September. Larvae were found in association with A. vexans, A. dorsalis, and C. inornata. It tolerates total salt concentrations up to 1900 p.p.m. It overwinters in the adult stage. Females bite after sunset. This is in agreement with the report of Hearle (1926). McLintock (1944) reports it to bite readily during the day and often troublesome to children.

Other Species

None of the other species of the subfamily Culicinae collected in the irrigated areas of Alberta including A. sticticus, A. intrudens, A. cataphylla, A. riparius, A. melanimon, and C. alaskaensis appeared in large enough numbers to be classed as serious pests.

Chaoborus (Chaoborus) flavicans and
Chaoborus (Chaoborus) americanus

C. flavicans was the more abundant of the two species. Larvae were found in association with one another. They were found mostly in semi-permanent and permanent bodies of water. Adults are abundant and were caught in the visual attractant traps. In 1956 there were two peaks of adult populations, the first on June 24 and the second on August 20. As the numbers of permanent bodies of water increase in the irrigated areas, adults of these species could become an annoyance in homes as they are readily attracted to lights.

C. The Seasonal Changes in Abundance and Distribution of Mosquito Larvae and Adults

The effect of irrigation on mosquito production in the irrigated plot for the 1956 season is shown in Figure 7. Mosquito production is highest during the irrigating period, which extends from approximately the first week in June to the last week in August. Mosquito production resulting from spring run-off is that shown during May in both the

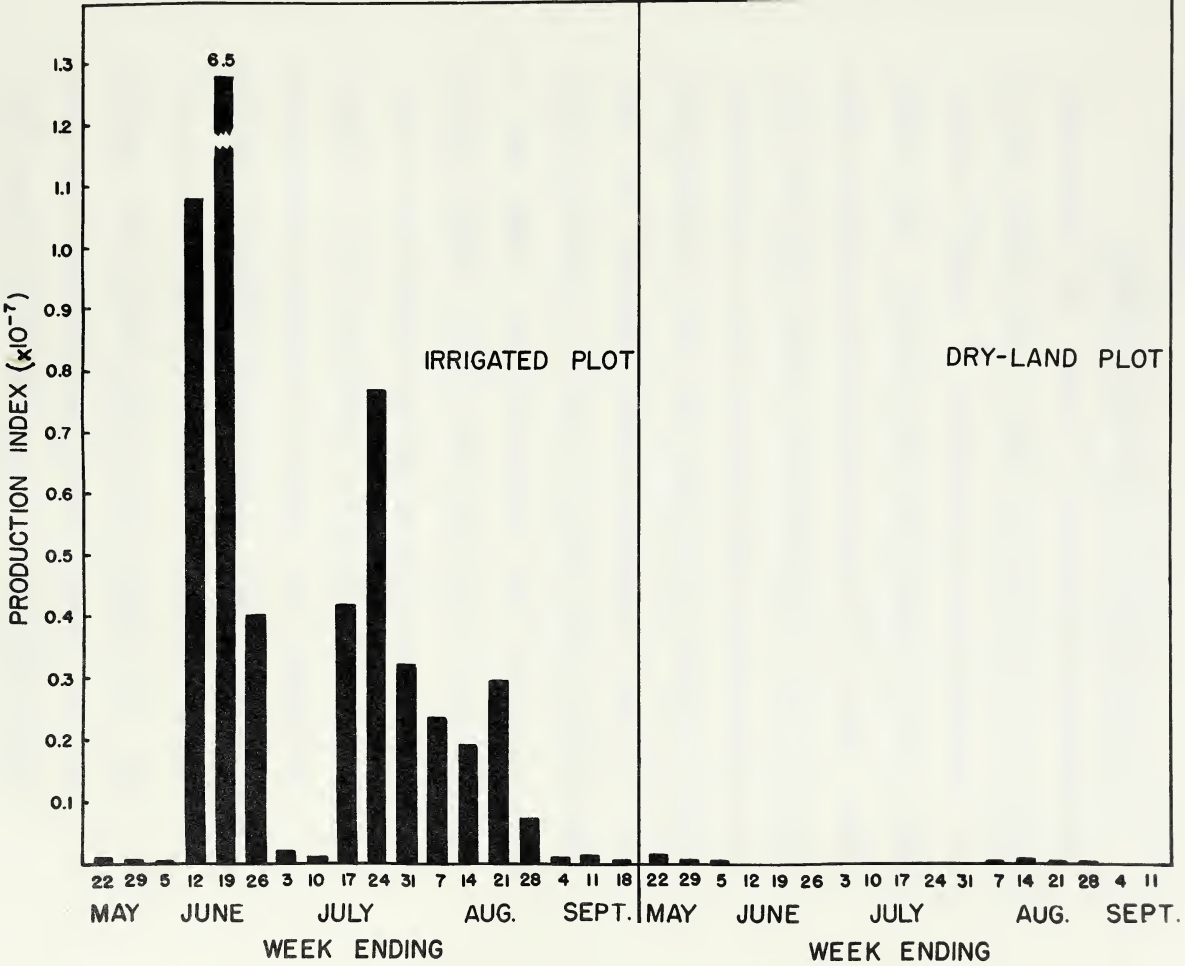

Figure 7. Mosquito larval production in irrigated and dry-land plots studied in 1956 in the Eastern Irrigation District near Brooks, Alberta.

irrigated and dry-land plots. This is insignificant in comparison with the production during the irrigating period.

Rainfall during the 1956 season was responsible for some of the mosquito production in the study area. This is shown in the dry-land records (Figure 7) during the period August 7 to August 28. Rainfall for the months of May, June, July, August and September was 0.75, 2.23, 0.88, 3.73 and 1.50 inches respectively. The mosquito production in the dry-land plot during August is attributed to the fact that 2.19 inches of rain fell in a 48-hour period on August 1 and 2. This was sufficient to cause run-off into depressions in the land. The subsequent 1.54 inches of rain during August maintained the water level in the pools long enough for the development of the larvae to be completed. The mosquito larval production (Figure 7) during the irrigating period is shown by two peaks, the first during the period June 12 to June 26 and the second during the period July 17 to August 28. The first and highest peak is the result of the first major application of irrigation water to all cultivated, forage and pasture crops. The second and lesser peak, which extends over

a longer period of time, is the result of second and third applications of irrigation water mainly to forage and pasture crops.

Figure 8 shows the seasonal mosquito production in the three plots studied in 1957. It is evident that mosquito production is highest during the irrigating season in the three plots. Results from the 1957 study further substantiated the results of 1956, showing that mosquito production from spring run-off is insignificant when compared with the production during the irrigating season.

The highest mosquito production is shown in Plot 1 (Figure 8). The plot was located in an irrigation development that has been in operation for approximately 40 years. It was found that all of the factors characteristic of this plot contributed to mosquito production. Seeded hay fields and irrigated pastures, which are essential to livestock production, are very common in the area. These are irrigated at least twice, and in many instances three times, a season. Along with poor drainage facilities, irrigated pastures provide very suitable breeding grounds for mosquitoes. Irrigation water from grain

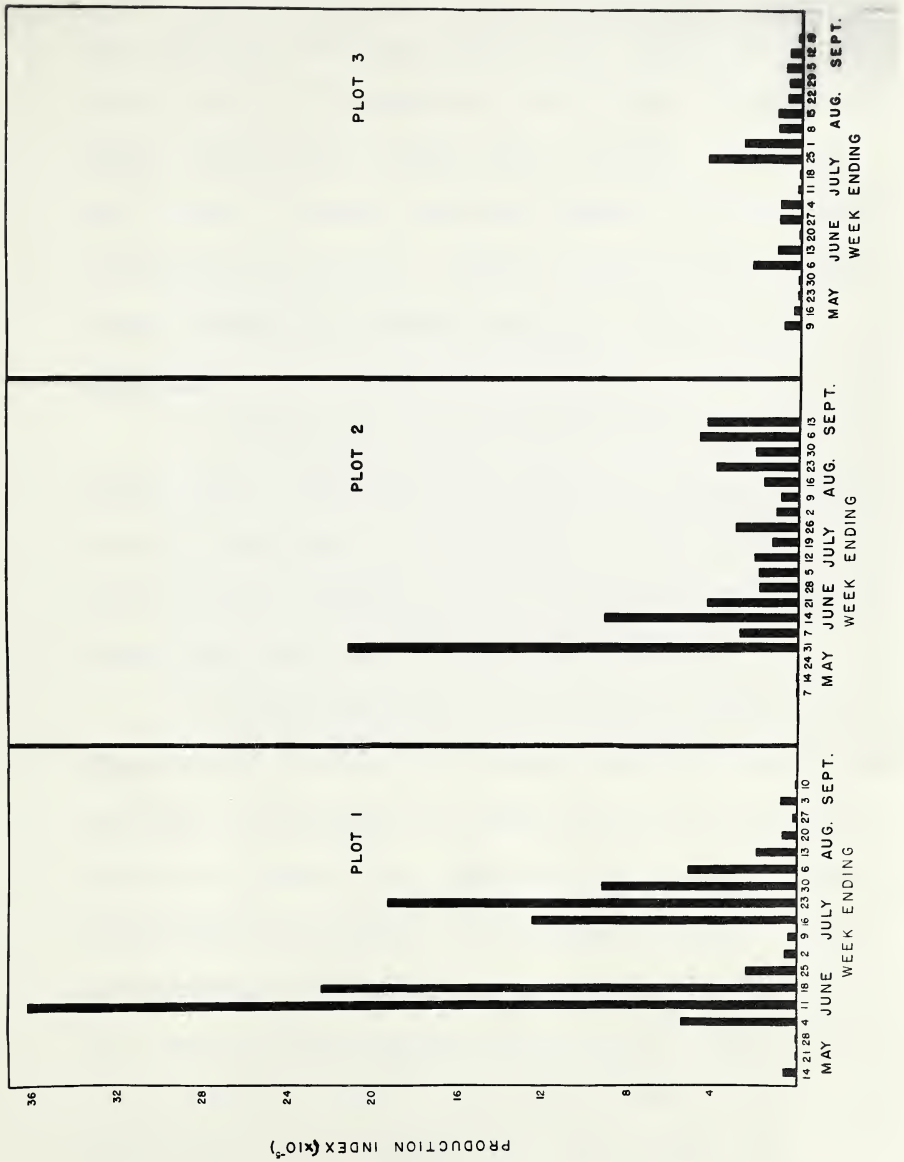

Figure 8. Seasonal mosquito production in 1957 in Plots 1, 2, and 3 at Rolling Hills, Hays, and Taber, respectively.

fields, hay fields, and pastures is allowed to drain into roadside ditches (Figures 9 and 10). The roadside ditches (Figure 11) serve as a great source of mosquito production. Seepage pools (Figure 12) along main canals, laterals, and supply ditches are very common in this older irrigation district. These seepage pools breed large numbers of Culex tarsalis and Culiseta inornata.

The major industry in Plot 2 is the production of cereal crops such as wheat, oats, barley, and flax, and the major industry in Plot 3 is row crops such as sugar beets, corn, beans, canning peas, and potatoes.

The mosquito production in Plot 2 is higher than in Plot 3. It is evident that proper drainage facilities in Plot 2 did not eliminate mosquito production. This is due to poor water management practices. The water is used indiscriminately throughout the season without regard for crop losses because of too much water. The crops grown in Plot 2 are low priced crops, therefore it is cheaper for the farmer to sacrifice small portions of his crop than it is to control flooding and improve his practice. In Plot 3 the crops require a more rigid

Figure 9. An irrigated pasture, near Rolling Hills, Alberta, where the excess water from irrigation is drained into a roadside ditch. The pasture and the roadside ditch are great sources of mosquito production.

Figure 10. The typical condition of roadside ditches in the Eastern Irrigation District into which waste water from irrigated fields is allowed to accumulate.

Figure 11. Typical roadside breeding places for mosquitoes in Plot 3 near Taber, Alberta, during the summer of 1957.

Figure 12. Seepage pool along a main canal near Rolling Hills, Alberta.

irrigating regime. The water is applied to row crops at regular intervals and in specified amounts. This type of regime minimizes the amount of waste water and at the same time the mosquitoes which might breed.

From these observations it can be concluded that the purposes of proper drainage facilities can be vitiated by improper farming and water management practices.

Figure 13 shows the seasonal changes and the relative abundance of mosquito larvae and adults of the seven species common in the three plots studied in 1957.

There is no quantitative relationship between the larval and adult population. There is, however, a qualitative reflection in larval production peaks in later adult peaks. The reasons for the lack of quantitative relationship are (1) as already indicated the larval index is a comparative measure rather than an absolute measure of larval population, (2) adult mosquitoes disperse over larger areas so that the samples from visual attractant traps could include adults which bred outside the study area and exclude those which bred in the study area, and (3) the

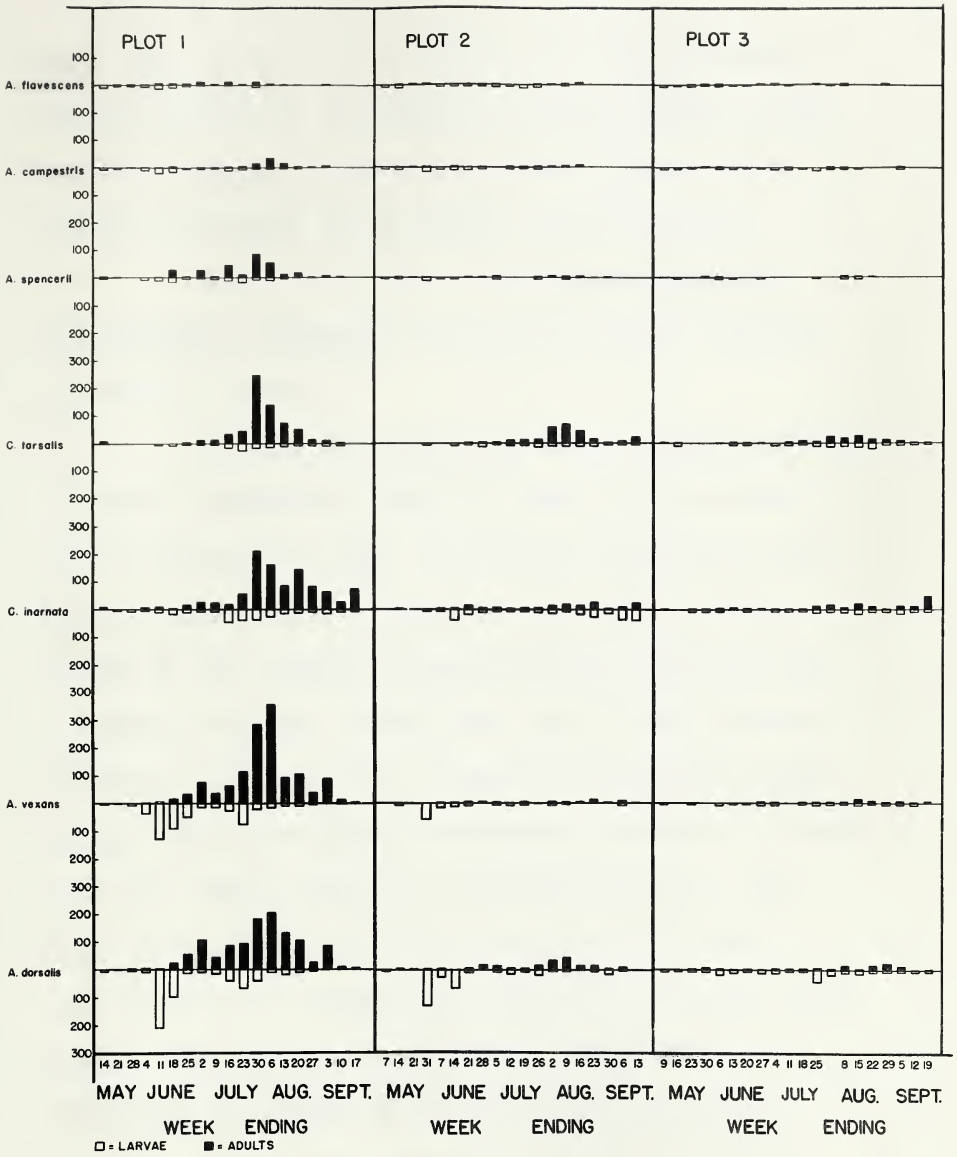
PLOT 1
PLOT 2
PLOT 3
A. flavescens
A. compestris
A. spencerii
C. tarsalis
C. inarnata
A. vexans
A. dorsalis
14 21 28 4 11 18 25 2 9 16 23 30 6 13 20 27 3 10 17
7 14 21 31 7 14 21 28 5 12 19 26 2 9 16 23 30 6 13
9 16 23 30 6 13 20 27 4 11 18 25 8 15 22 29 5 12 19
MAY JUNE JULY AUG. SEPT.
WEEK ENDING
□ = LARVAE ■ = ADULTS

Figure 13. The seasonal changes and relative abundance of larvae and adults of seven species common to Plots 1, 2 and 3 near Rolling Hills, Hays and Taber during 1957.

life span of adults is longer than the developmental period of the aquatic stages (Stage, 1936 and Stage et al. 1947), therefore, there is a greater prospect of an adult being sampled.

Figure 13 shows that Culex tarsalis and Culiseta inornata are the two major species in Plots 2 and 3.

Figure 14 shows the total weekly catches of adult mosquitoes taken in each of the three plots studied in 1957. The adult populations in Plots 1 and 2 reach peaks on the weeks ending August 6 and August 8 respectively, followed by a gradual decline toward the end of the season. In Plot 3 (Figure 14) a similar situation occurs except that the peak of mosquito abundance extends over the period August 1 to September 5. The peak on October 3 is the result of the final application of irrigation water to the sugar beet crop. When the data in Figure 14 are compared with data in Figure 8, there is no similarity between the seasonal changes in the larval and adult abundance.

The data from the two visual attractant traps operated near Brooks, Alberta, are summarized in Figures 15, 16, 17, and 18. It is shown in

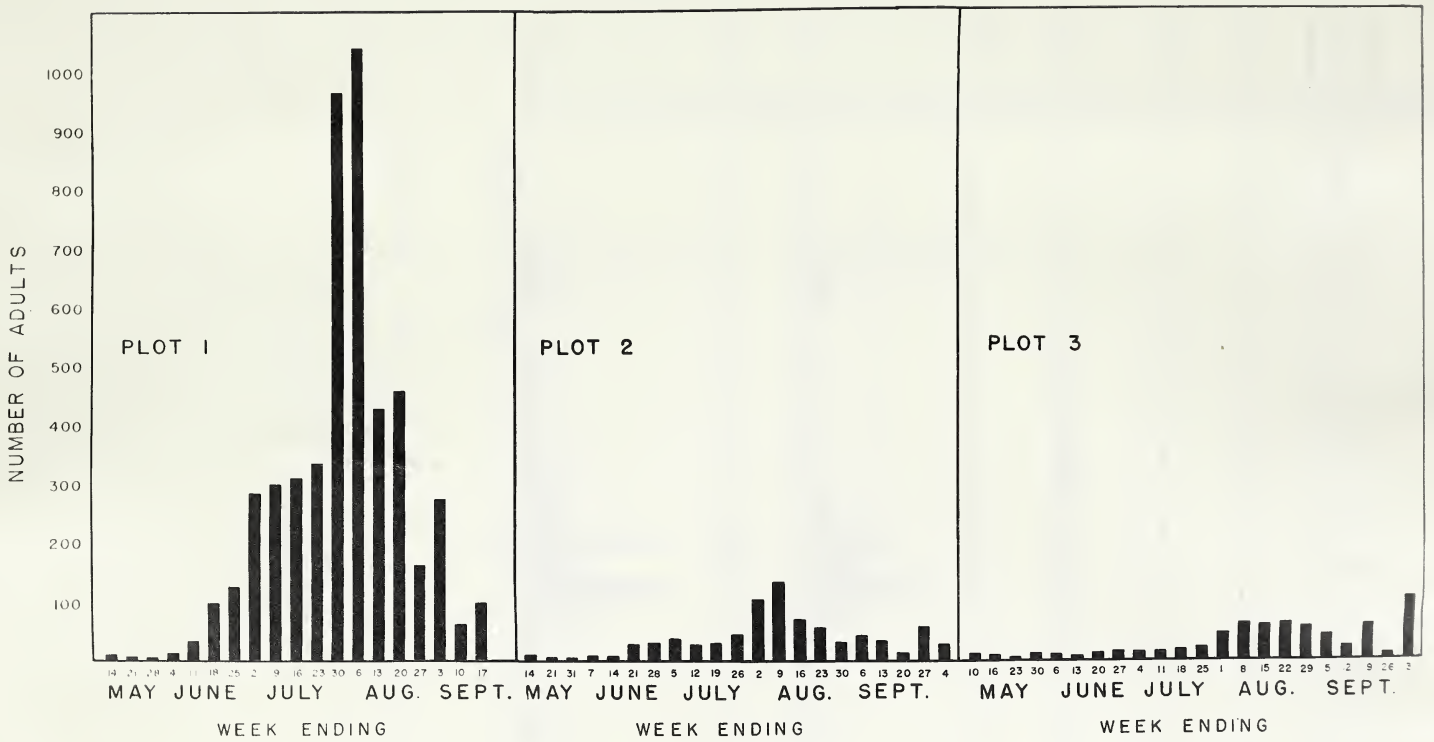

Figure 14. The total weekly catches of adult mosquitoes in 1957 taken in visual attractant traps in Plots 1, 2 and 3 at Rolling Hills, Hays and Taber, respectively.

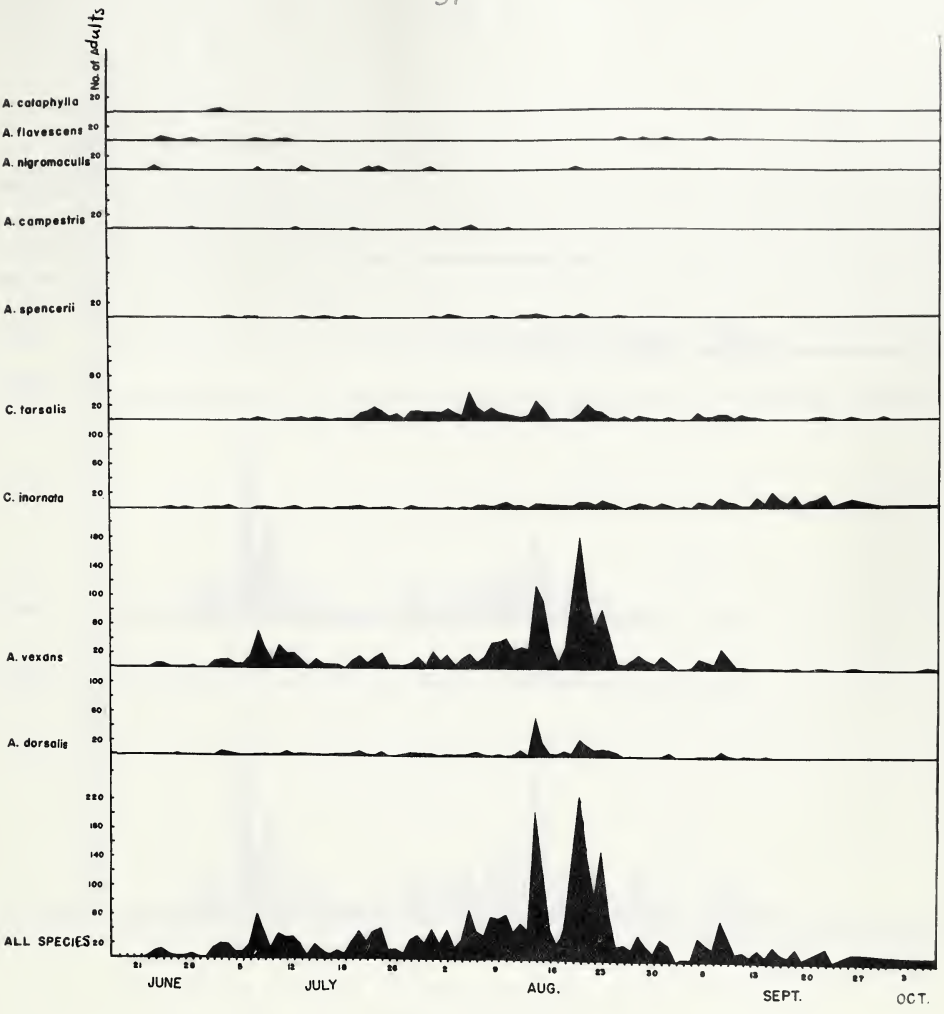

Figure 15. The total daily catches of female mosquitoes in Trap 1 in Brooks, Alberta, in 1956.

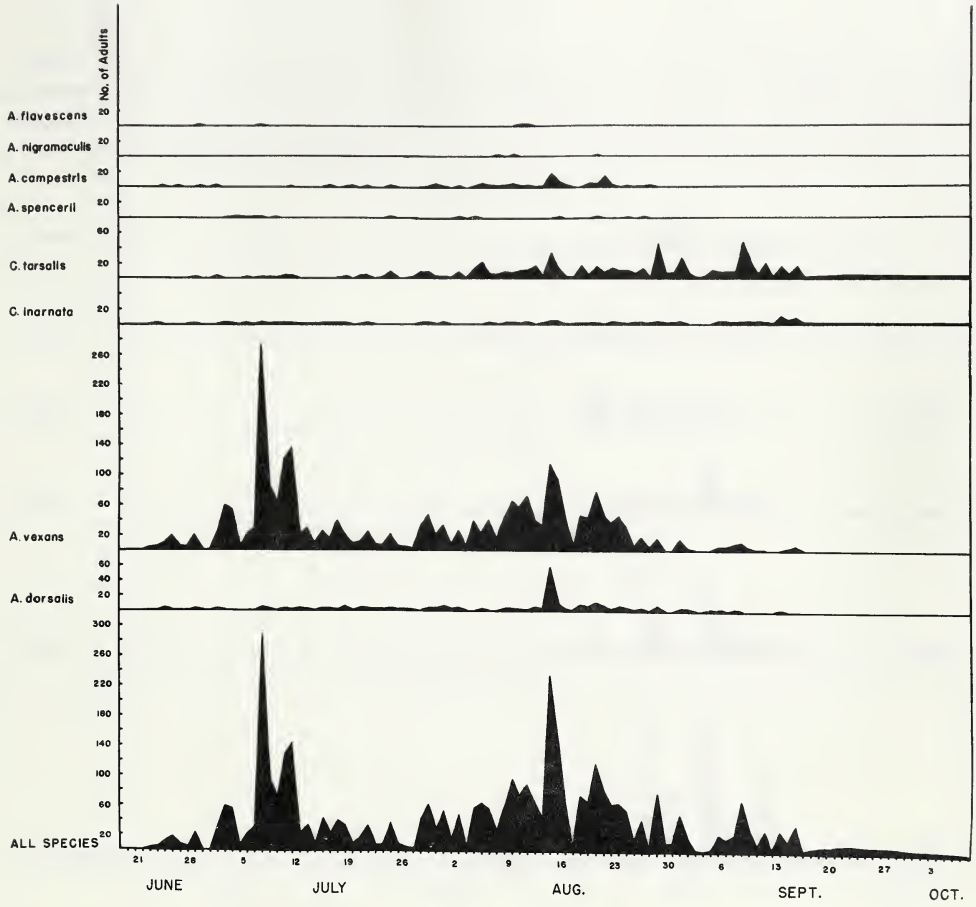

Figure 16. The total daily catches of male mosquitoes in Trap 1 at Brooks, Alberta, in 1956.

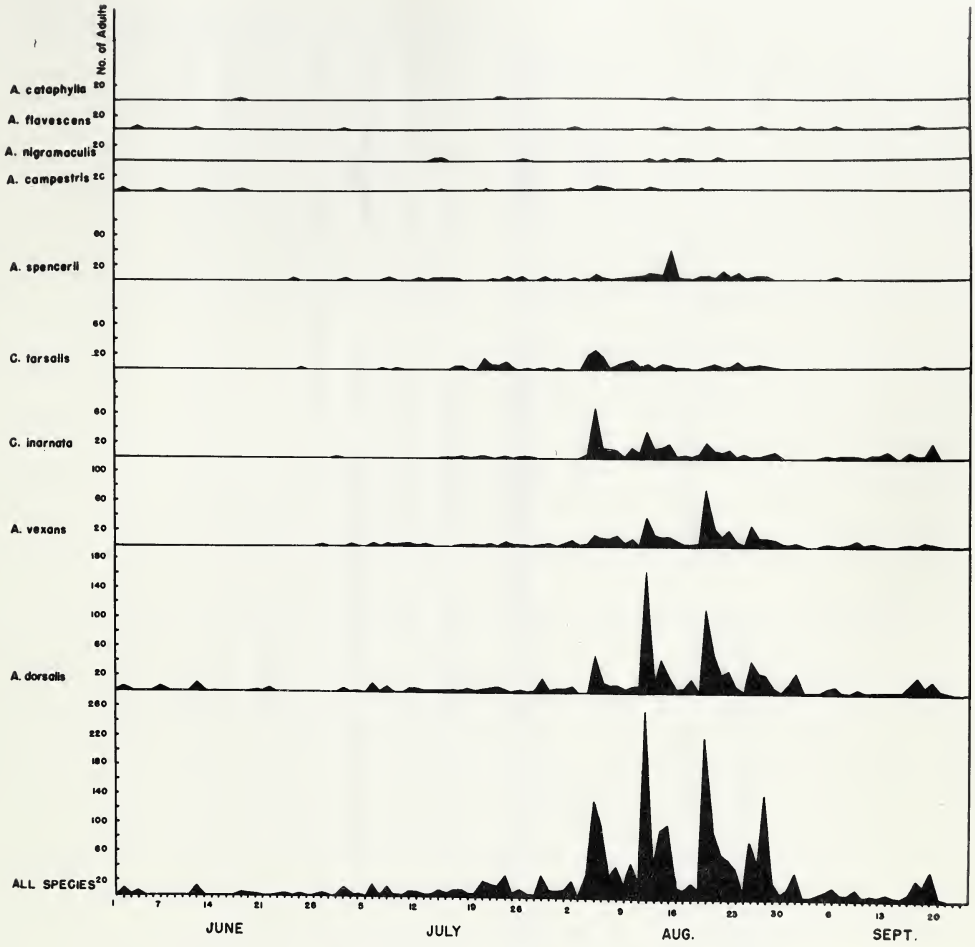

Figure 17. The total daily catches of female mosquitoes in Trap 2 near Brooks, Alberta, in 1956.

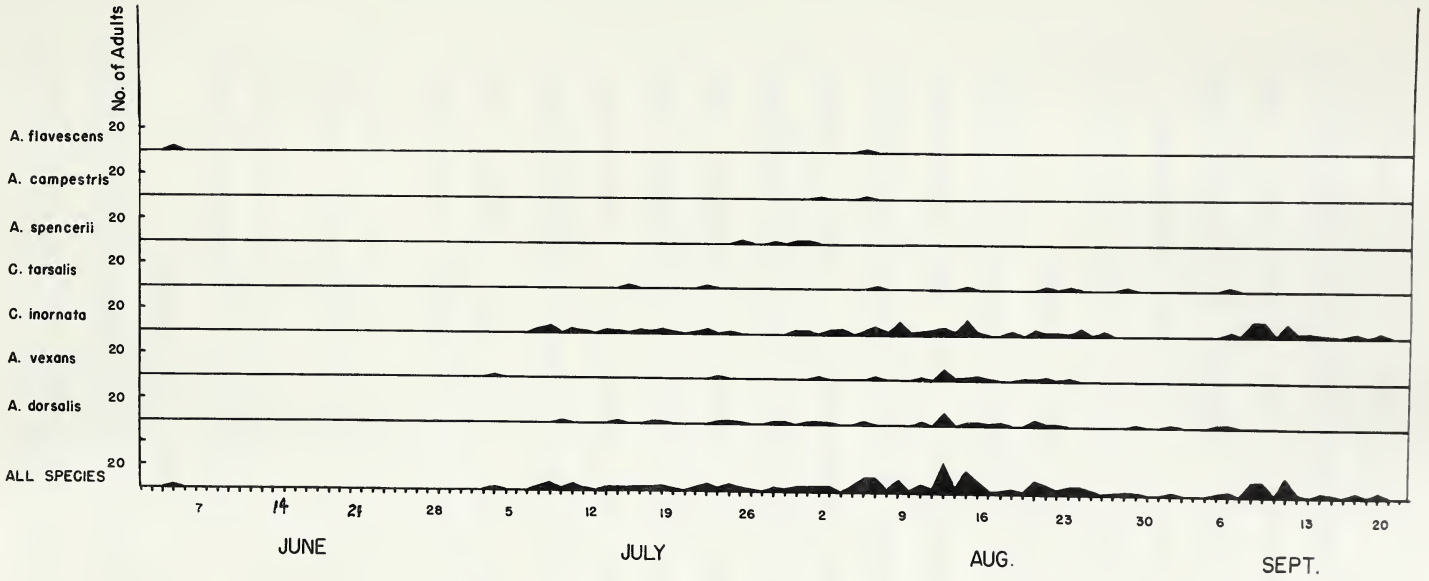

Figure 18. The total daily catches of male mosquitoes in Trap 2 near Brooks, Alberta, in 1956.

Figures 16 and 18 that males of all species except C. inornata were more abundant at the sheltered than at the open site. The most abundant males were those of A. vexans. They showed two peaks of abundance, the first peak in the period July 5 to July 12 and the second peak August 7 to August 23. It is evident that dense vegetation is a habitat preferred by males. This phenomenon undoubtedly has been observed by other workers, but has not been reported. Microclimatic conditions such as lower temperature, higher relative humidity and lower wind velocities would make dense vegetation a favorable resting place for male mosquitoes. Another factor that should be considered in explaining this behaviour is the availability of food. West and Jenkins (1951) have claimed that males of A. communis under laboratory conditions ingested plant juices and nectars of plants. Dense vegetation in yards, fields and valleys would be more succulent than the sparse prairie grass, and therefore presumably more attractive to the males.

Figures 15 and 17 show a slightly higher total female population in the sheltered site than in the open site. A. vexans females

were more abundant in the sheltered site. However, females of A. dorsalis, A. spencerii and C. inornata were more abundant in the open site. The remaining species showed no conspicuous difference in abundance between the two sites. The presence of relatively high numbers of females at each site could be attributed to the dispersion habits of the females. ("Dispersion" as defined by Provost, 1952). After mating, the female has two important functions to fulfil: (1) to seek food for ovarian development and (2) to seek oviposition sites and to lay eggs. In these processes the female would have to travel over considerably larger areas than the males and thus are more likely to be sampled.

The fluctuations in the populations from day to day were attributed to weather conditions.

The mosquito activity for each day during the period August 11 to August 20 for the four major species is shown in Figures 19, 20, 21 and 22. Figure 23 shows the temperatures, wind velocities and the relative humidity for the period August 11 to August 20. The activity was plotted from the hourly catches taken from the trap operated in Brooks in 1956. Counts of

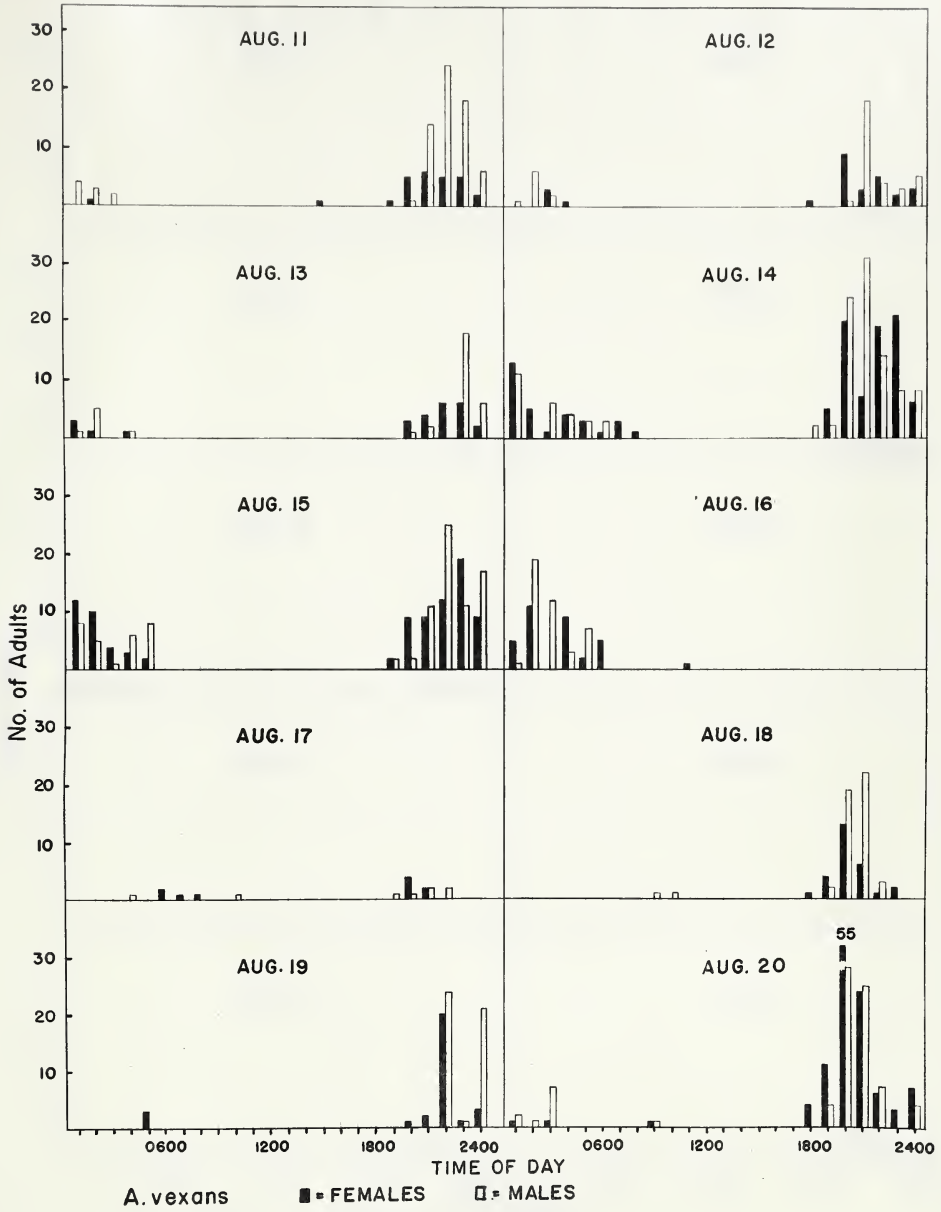

Figure 19. The daily activity of A. vexans adults for the period August 11 to August 20, 1956, at Brooks, Alberta.

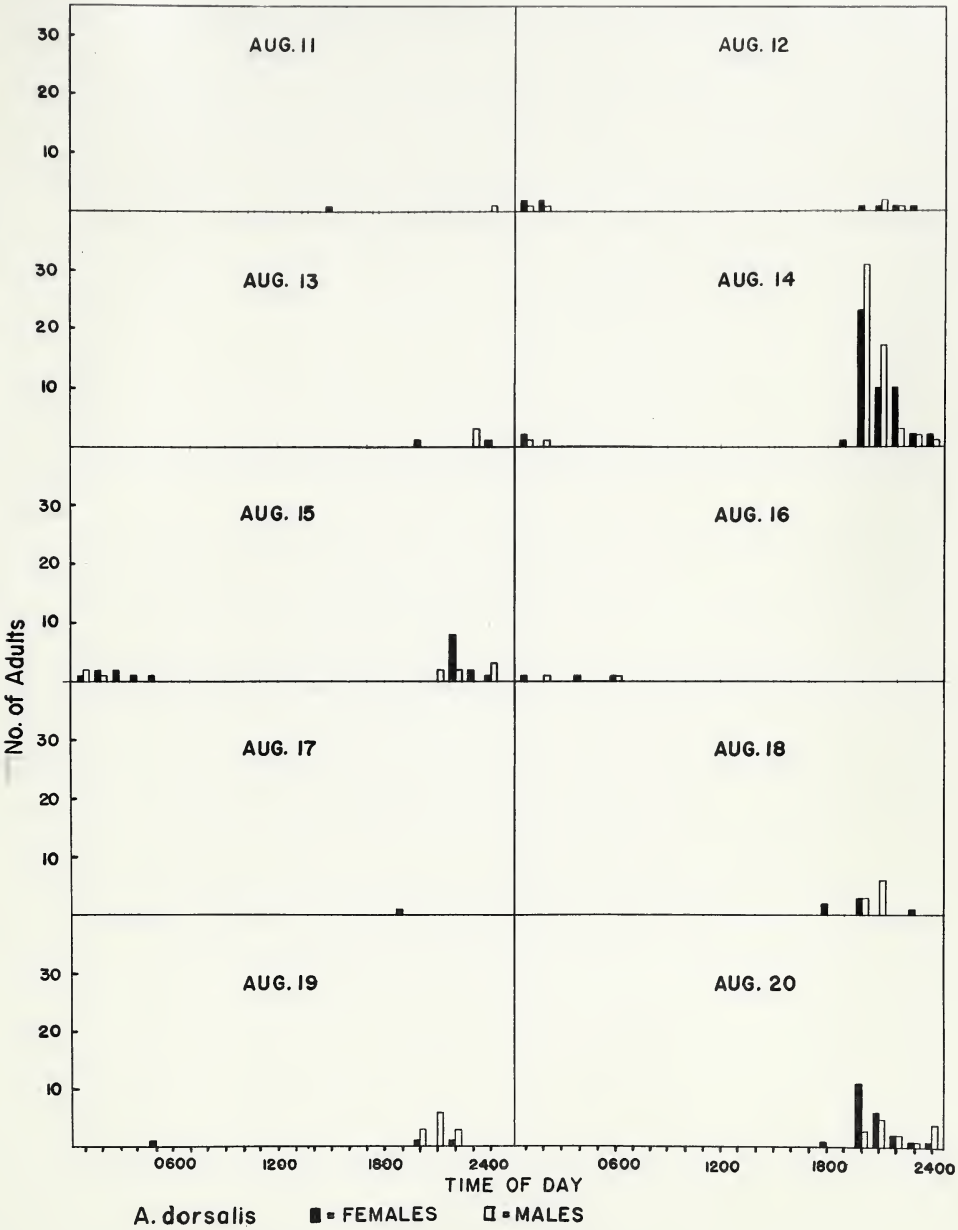

Figure 20. The daily activity of A. dorsalis adults for the period August 11 to August 20, 1956, at Brooks, Alberta.

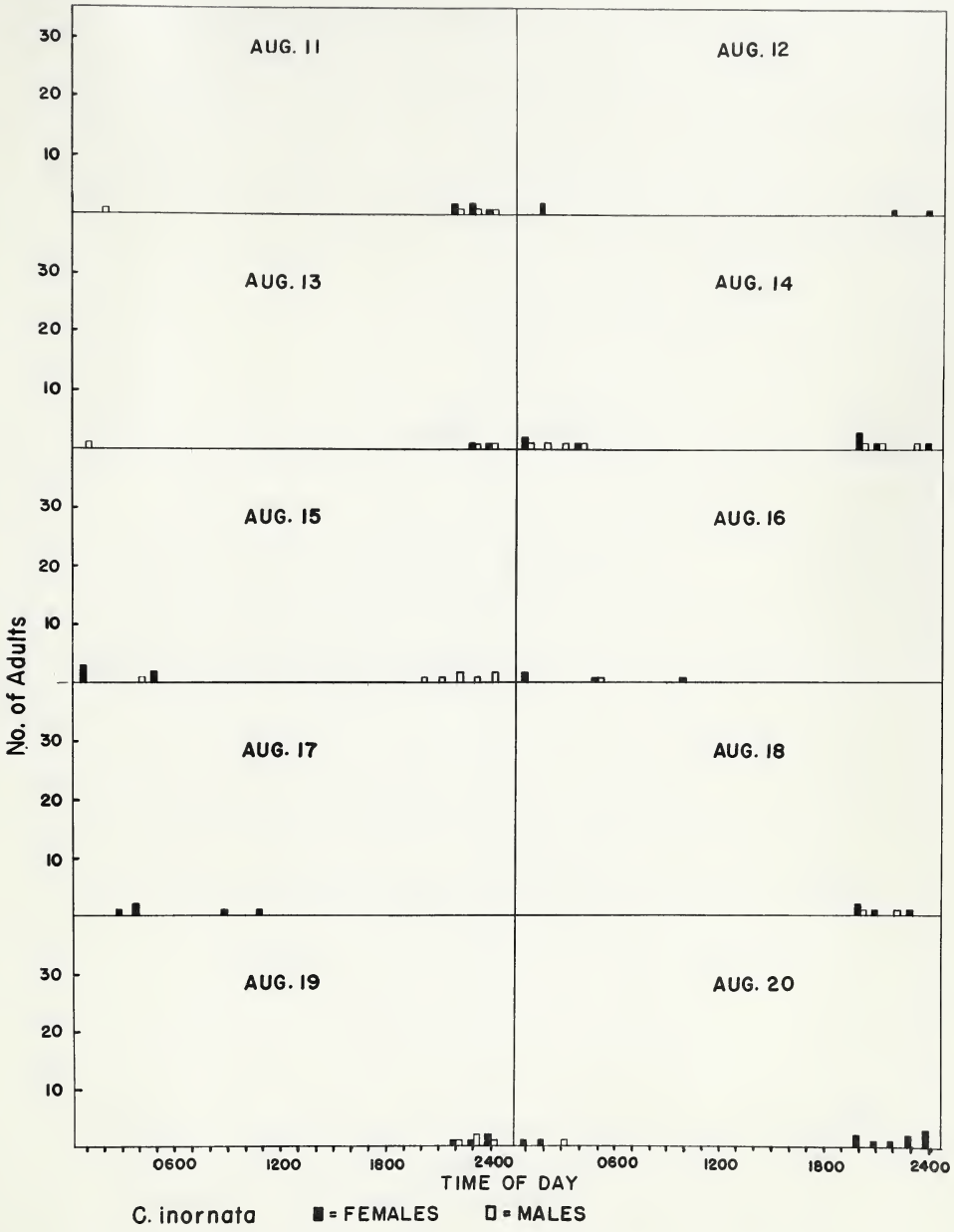

Figure 21. The daily activity of C. inornata adults for the period August 11 to August 20, 1956, at Brooks, Alberta.

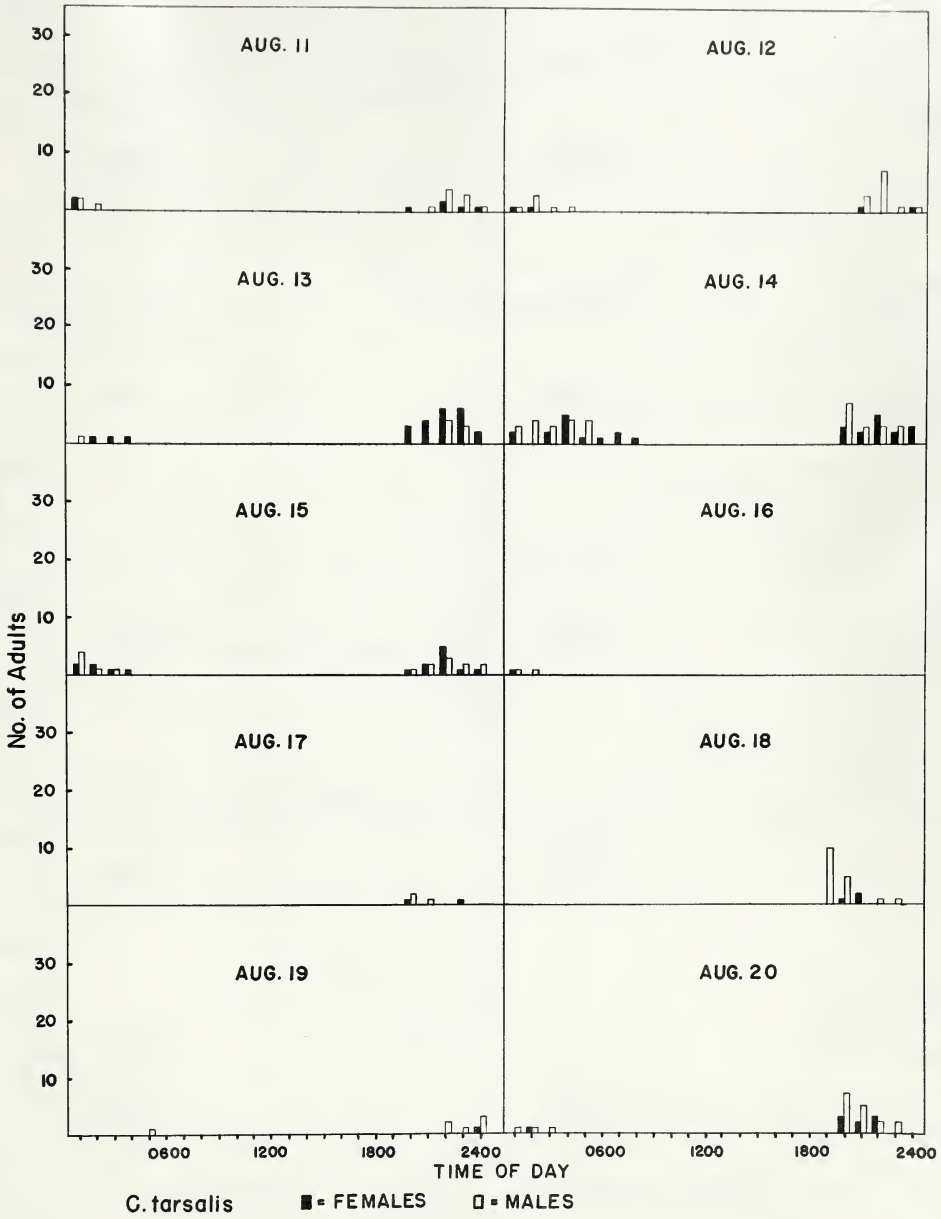

Figure 22. The daily activity of C. tarsalis adults for the period August 11 to August 20, 1956, at Brooks, Alberta.

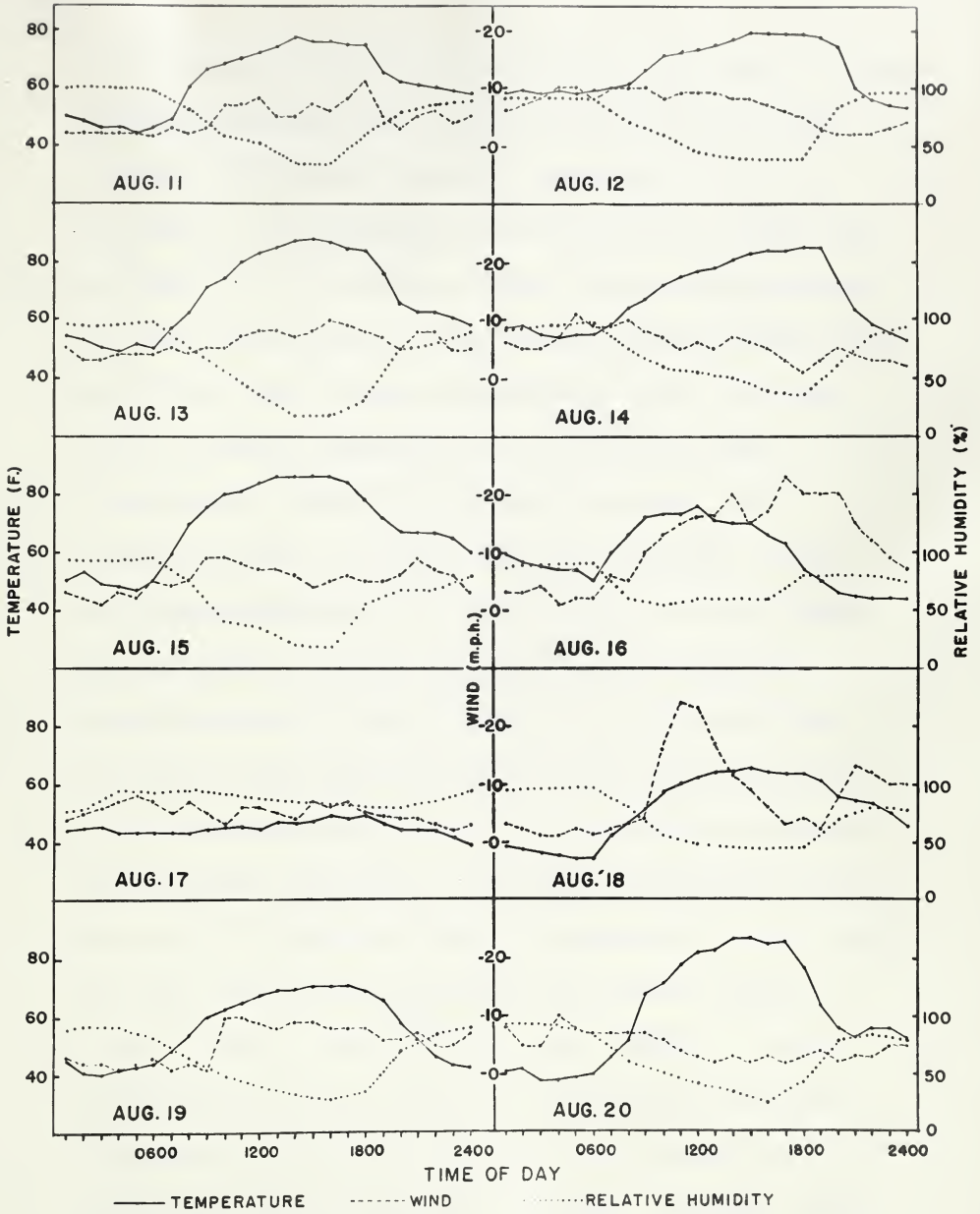

Figure 23. Hourly temperatures, wind velocities and relative humidities for the period August 11 to August 20, 1956, at Brooks, Alberta.

the numbers of mosquitoes landing and biting on an exposed forearm were taken at hourly intervals between 0300 and 2100 hours on August 11, 12, 13 and 14 to supplement the trap data during the periods of low catches. From these observations it was found that in the period between 0800 hours and 1700 hours female mosquitoes would land and bite in small numbers (1 to 1.6/min.) only immediately after the observer entered the sampling site. If the observer remained still for approximately 3 to 5 minutes, no bites would be recorded. It was concluded that prairie mosquitoes will bite at almost any time of the day when they are disturbed, and that the visual attractant mosquito trap was a reliable criterion of mosquito activity. The lack of mosquito attack on a still observer might be explained on the basis of the information presented by Brown (1951), Breev (1950), and Sippell et al. (1953). Breev has reported that vision in mosquitoes plays an important role in attack and that mosquitoes are attracted more to moving objects. He also states that darker colored animals are preferred to lighter colored ones. These findings are supported by the findings of Brown (1951) and Sippell et al. (1953).

Data presented in Figures 19, 20, 21 and 22 show that both the males and females of the four species are most active between 1800 hours and 0800 hours with some variation between the species. It is apparent that the major species of the irrigated areas are crepuscular and nocturnal in habit. It is evident from these figures that mosquito activity begins shortly before sunset and continues through to shortly after sunrise. During the earlier part of this period, temperature and light intensity are dropping and the relative humidity rising (Figure 23). The increase in relative humidity at the same time as a decrease in temperature would correspond to a decrease in saturation deficiency which, according to Hocking et al. (1950), is a factor influencing biting activity. The effect of light intensity on mosquito activity is not known, and this factor would be a very difficult one to investigate under field conditions because of the interrelating factors such as temperature, saturation deficiency, barometric pressure and wind. Hocking et al. (1950) and Hunter (1910) have reported correlations between cloudiness and mosquito attack which would indicate that light intensity has some effect. Biting and mating activity after sunset is further evidence that light intensity is an influencing factor.

The effects of wind on mosquito activity are not clear. There is, however, a reduction in activity when the wind velocities exceed 10 miles per hour. Apart from having a direct mechanical effect on mosquito activity, wind could have an indirect effect by increasing the evaporation rate.

D. Parasite and Predators on Mosquito Larvae

(a) Parasites

Larvae of C. inornata were found to be infected by a fungus (Figure 24) tentatively identified as Coelomomyces spp. This genus is in the Phylum Phycomcetes and in the Order Chrytridiales. According to Steinhaus (1947), the true systematic position of the genus is not clear.

This is the first report of fungal infection in mosquito larvae in Canada. The first infected larvae were collected at Brooks, Alberta, on August 8, 1956. In 1957, infected larvae were collected periodically during the period July 8 to September 3. It was not determined whether the fungus was pathogenic to the larvae. Hearle (1929) reported that presence of Coelomomyces spp. in the abdominal cavity of one A. flavescens female could have been pathogenic.

Figure 24. The resting sporangia of Coelomomyces spp. in the thoracic cavity of C. inornata.

According to Couch et al. (1945) fungal parasites are of little importance in the reduction of mosquito populations. Muspratt (1946) however estimated the mortality of Anopheles gambiae due to a species of Coelomomyces to be as high as 95 per cent.

(b) Predators

Representative samples of aquatic insects in the pools sampled in 1957 were collected. The insects were identified by Dr. G. E. Ball and Mr. W. Klassen. The possible predators on mosquitoes are listed below.

Order: Coeloptera

Family: Dytiscidae

Genera:	Dytiscus	(larvae and adults)
	Graphoderes	(larvae and adults)
	Ilybius	(larvae and adults)
	Hydrobius	(adults)
	Coelambus	(larvae and adults)
	Rhantus	(larvae and adults)
	Laccophilus	(larvae and adults)

Family: Hydrophilidae

Genera:	Helophorus	(larvae and adults)
	Laccobius	(larvae and adults)

Genus: Berosus (larvae and adults)
Genus: Tropisternus (larvae and adults)
Genus: Enochrus (larvae and adults)
Genus: Hydrobius (larvae and adults)

Family: Gyrinidae
Genus: Gyrinus (adults)

Order: Diptera
Family: Stratiomyiidae
Genus: Stratiomys (larvae)

Family: Tipulidae
Genus: Tipula (larvae)

Family: Syrphidae
Genus: Tubifera (larvae)

Order: Hemiptera
Family: Gerridae
Genus: Gerris (adults)

Family: Notonectidae
Genus: Notonecta (nymphs and adults)

Family: Corixidae (adults)

Family: Belostomatidae (adults)

Order: Odonata
Family: Libellulidae (nymphs)

Family: Aeschnidae

Genus: Aeschna (nymphs)

Family: Lestidae

Genus: Lestes (nymphs)

Order: Trichoptera

Family: Limnephilidae

Genus: Limnephilus (larvae)

From observations made during 1956 and 1957, predators on mosquito larvae appear to be of little importance in the reduction of the population.

E. Identification of Blood Meals of Engorged Mosquitoes

The blood meals of engorged females collected in the irrigated areas of Alberta were identified by means of serological precipitin tests. These studies were conducted in cooperation with Mr. A.E.R. Downe, Veterinary and Medical Entomology Unit, Ottawa. To date the results on the identification of blood meals of engorged females taken in the visual attractant trap are not available. The results on the specimens collected in or around farm buildings during 1955 and 1956 are shown in Table I.

Table I. The results of precipitin tests on blood-engorged mosquitoes collected in buildings and farm yards near Brooks, Alberta in 1955 and 1956

Species	No. Tested	No. feeding on							Multiple feeding	No. Negative
		Cattle	Pigs	Fowl	Humans	Horses	Sheep	Dogs		
A. campestris	3	1	1				1			
A. cataphylla	19	6	3				5	1		4
A. cinereus	3	2					1			
A. dorsalis	160	80	20	16			25	2	1 (pig and human) 1 (cattle and fowl) 2 (beef and fowl)	13
A. flavescens	4	1	2				1			
A. intrudens	6	3	1	1						
A. nigromaculis	3	2					1			
A. riparius	3		3							
A. spencerii	91	44	1	1			28	2	1 (cattle and sheep)	14
A. vexans	154	87	21	13		1	12	4	1 (pig and fowl) 1 (horse and cattle) 1 (horse and pig)	14
C. tarsalis	23		1	15	1				1 (human and chicken)	5
C. inornata	17	9	2				1			5
Total	486	235	55	46	1	1	75	9	9	55

It should be remembered that all of the mosquitoes mentioned in these tests were collected in the rather restricted environment of farm buildings and, because of this, the results indicate neither true host preference nor the full range of acceptable host species. The tests gave evidence on feeding on two different hosts for only about one per cent of the engorged females taken in this environment. This is in agreement with the work of Rempel et al. (1946) in Saskatchewan. About 12 per cent of the total number of specimens tested gave no serological reaction. This was probably due to the destruction of the blood meal by digestive processes (Downe, 1957 and West et al., 1952).

F. Rate of Development of Mosquitoes

A thorough study on the rate of development of mosquitoes in irrigated areas could not be made because of inadequate personnel and equipment. However, it was found that the post-hatching developmental period for a mixed population consisting of A. dorsalis, A. vexans and A. flavescens was 335 degree days, assuming that the threshold of development is 32°F. This degree day figure falls within the range

reported for northern species by Hocking et al. (1950) and Haufe et al. (1956).

An observation worthy of note at this point is that in certain pools the larvae and pupae were much smaller than those of the same species in other pools. The causes for this are not known.

VI DISCUSSION AND RECOMMENDATIONS

A. Discussion

The areas studied during 1956 and 1957 were representative of the irrigated areas of southern Alberta. The results of these studies definitely show that mosquito production is directly associated with irrigation. It was shown that normal precipitation was of little significance from the standpoint of mosquito production.

Irrigation agriculture in southern Alberta is tending towards more livestock production. The range lands all around the irrigation projects are used for summer grazing for large herds. Winter feed is grown in the irrigated areas. Some livestock is pastured in irrigated pastures. Therefore large acreages

are utilized for production of feed for livestock. Irrigated pastures and fields growing forage crops are usually less well prepared than those devoted to the growing of cultivated crops. This is largely because most of these crops can stand more waterlogging than cereal or row crops.

The undulating to gently rolling topography of the irrigated areas contributes to mosquito production. Low spots and depressions cannot be completely eliminated without expense and therefore harbor water long enough to produce mosquitoes. The data obtained in this study have shown that even in very well engineered districts mosquitoes are produced. This points out that farming practices play an important integral part with proper engineering in prevention of mosquito breeding. The heavy soils of the irrigated areas help to maintain surface water accumulations. In the low areas these repeated accumulations cause heavy deposits of alkali salts (Figure 25). Land with high concentrations of alkali salts make such areas unsuitable for crop production and they soon become classed as waste land which often serves as reservoirs for run-off water from irrigated fields. This situation is common in most older irrigation

Figure 25. The alkali salt deposits resulting from repeated accumulation of water in poorly drained areas in the Eastern Irrigation District near Brooks, Alberta, 1956.

districts and is a prolific source of mosquitoes.

Roadside ditches are another major source of mosquitoes. More careful planning in the building of roads could help reduce mosquitoes and prevent deterioration of the road bed. Figure 26 shows broken road shoulders in irrigation districts where run-off water from fields is allowed to accumulate in roadside ditches.

The data obtained in this study show that adult mosquitoes are most abundant during July and August. During this period farming operations are at their peak. The losses suffered through inefficiency of agricultural and other workers due to mosquitoes are difficult to evaluate. However, the inhabitants of the irrigated areas have accepted mosquitoes as an occupational hazard and have adopted ways of living with the pest. Repellents, head nets, and the timing of their work to the periods of least mosquito attack are some of the ways in which they cope with the problem. Livestock probably suffer most from mosquito attack and with probable losses to the producer. Economic losses are possible through the loss of blood (Stage et al. 1936 and Munroe et al. 1957) as

Figure 26. Road bed deterioration as a result of irrigation water accumulation in roadside ditches.

well as through the reduced feeding due to the discomfort and annoyance from the pest. During 1956 and 1957 it was observed that on many occasions at night cattle would not feed at all. The cattle congregated in groups, stamping their feet, snorting and switching their tails. This grouping could be a protective behaviour against mosquitoes, similar to that shown by behaviour in northern reindeer described by Breev, (1951). Breev states that reindeer achieve protection by (1) running against the wind, (2) running into water, and (3) grouping. He found that when biting flies become troublesome, groups of reindeer begin to form, the fawns, mothers, and the weak ones in the centre, and older animals on the outside. The nervous animals formed the periphery and attracted the insects by their movements, thus protecting the rest of the animals. He showed that the attack on the animals on the periphery was ten times as great as that on the animals in the centre. There, to date, is no practical way of protecting livestock in the field from mosquito attack.

Until we know more about how insecticides can be used in irrigation water, chemical

control is not feasible. Such a large sparsely settled area cannot bear the cost of an annual chemical control program. However, space and residual sprays are being used around dwellings and farmsteads and give relief from mosquitoes.

Two of the four most abundant species breeding in irrigation water, namely, Culex tarsalis and Culiseta inornata, have been incriminated as vectors of western equine encephalomyelitis from wild host to man. It is therefore puzzling that there have been only six reported cases of human encephalomyelitis in Alberta, especially when the incriminated vectors are established and breeding prolifically in the irrigated areas. Rempel (1953) from Saskatchewan has reported 543 human cases of the disease of which 44 were fatal in 1941. During the summer of 1955 practically all pooled samples of C. tarsalis adults collected in the Milk River Valley of Montana, approximately 150 miles south of Medicine Hat, were positive for western equine encephalomyelitis. It is probable that the incidence of the virus is similar in Canada. Results from precipitin tests on mosquitoes in irrigated areas of Alberta show a low incidence of feedings on more than one host. This probably

accounts for the low incidence of mosquito-borne diseases. West (1956) has summarized the potential danger of mosquito-borne diseases in Canada. It is quite evident that the question of mosquito-borne diseases should not be overlooked, and warrants further study especially in the irrigated areas of southern Alberta.

B. Recommendations

1. The water users of all irrigation districts must be educated to use water with a minimum of waste. This would fulfil a two-fold purpose: (1) reduce mosquito production and (2) prevent waterlogging of the soil.

2. A programme of reclamation of existing wasteland in irrigated areas must be initiated. This would also reduce mosquito breeding places and would make more land available for crop production.

3. Some of the modern insecticides must be tested as larvicides in irrigation water. This information would be very useful in the event of a mosquito-borne epidemic.

4. Proper drainage systems as well as supply systems must be incorporated in future irrigation districts.

5. In existing irrigation districts a gradual reconstruction programme to provide drainage must be initiated.

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